

(19) World Intellectual Property Organization
International Bureau



PCT



(10) International Publication Number
WO 2009/088280 A2

(51) International Patent Classification:

G01N 27/333 (2006.01) **G01N 27/62 (2006.01)**

Malaysia, 57000 Kuala Lumpur (MY). **ABDULLAH, Ali, Zaini, B** [MY/MY]; Minos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(21) International Application Number:

PCT/MY2009/000009

(74) **Agent: TAN, Boon, Leng;** Boon IP Enterprise, D-8-8 Seri Puri, Jln Aman, 52100 Kuala Lumpur (MY).

(22) International Filing Date: 5 January 2009 (05.01.2009)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) Priority Data:

PI20080015 4 January 2008 (04.01.2008) MY

(71) Applicant (for all designated States except US): **MIMOS BERHAD** [MY/MY]; Technology Park Malaysia, 57000 Kuala Lumpur (MY).

(72) Inventors; and

(75) **Inventors/Applicants (for US only):** **HASHIM, Mohamad, Faizal** [MY/MY]; Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **YUSOFF, Yuzman** [MY/MY]; Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **KAMAL, Wan, Hasmi** [MY/MY]; Minos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **MUSA, Rohana** [MY/MY]; Mimos Berhad, Technology Park Malaysia, 57000 Kuala Lumpur (MY). **RAZALI, Nabihah** [MY/MY]; Mimos Berhad, Technology Park

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: ADAPTABLE ANALOG READ-OUT INTERFACE CIRCUIT FOR ISFET BASED SENSOR

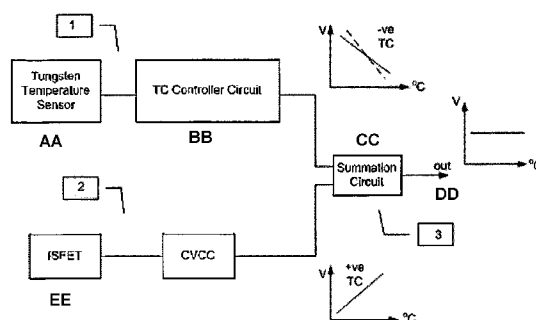


Figure 1: Block diagram of analog read-out interface circuit

1

AA capteur de température en tungstène

BB circuit de commande TC

CC circuit de cumul

DD sortie

EE ISFET

1 diagramme d'un circuit à interface de lecture analogique

(S7) Abstract: An adaptable analog read-out interface circuit for ion-sensitive field effect transistor (ISFET) that uses a tungsten temperature sensor to improve the thermal stability of the ISFET. The improvement is achieved by summation of the positive temperature coefficient of the ISFET and the negative coefficient of the resistor temperature dependence.



Declaration under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *without international search report and to be republished upon receipt of that report*

TITLE OF THE INVENTION

Adaptable analog read-out interface circuit for ISFET based sensor

TECHNICAL FIELD

5The present invention relates to the adaptable analog read-out interface circuit for hydrogen ion sensors, and more specific for ion-sensitive field effect transistor (ISFET) pH sensor. This interface circuit is integrated together with an additional tungsten temperature sensor in order to improve the ISFET temperature dependence. This invention improves the thermal stability of the ISFET and thus allows a more accurate pH measurement.

10

BACKGROUND

Advancement in microelectronic and semiconductor technology has enabled new-capabilities in the field of sensor development, particularly of pH sensors based on field effect transistor.

Ion-sensitive field effect transistor (ISFET), a kind of micro-sensing device, was invented by 15Bergveld in 1970 and developed quickly thereafter.

ISFET structure is very similar to conventional MOSFET, except for the standard metal gate is replaced by reference electrode and electrolyte. The threshold voltage of ISFET is changed due to the change in concentration of hydrogen ions (expressed by the pH change of the electrolyte), so that the voltage response is often used as an output signal of the ISFET.

20To capture the electrical signal generated by a sensor, the sensor (ISFET) must be accompanied with an analog read-out interface.

The ISFET has problems in reproducibility and stability due to temperature dependent drift. Every improvement in these aspects will increase the usage of ISFET. The invented analog read-out circuit provides solution in improving ISFET temperature dependence.

25BACKGROUND ART

There are three patents that deal with our application area.

US Patent 4879517

Title: Temperature compensation for potentiometrically operated ISFETs

This application only uses a resistor temperature sensor. There is no means for adjustment and tuning.

US Patent 6906524

5 Title: Electronic circuit for ion sensor

This application is without any temperature compensation at all and uses a bridge type technique as ion sensing mechanism.

10 US Patent 20070138028

Title: PH-Change sensor and method

This application uses complementary ISFET-MOSFET pair technique for ion sensing mechanism what is different and elaborated.

15

PRINCIPAL CONCEPT

The principle of this readout circuit is to cancel the positive temperature coefficient of ISFET by the negative temperature coefficient of a tungsten resistor device. Temperature coefficients of both devices are combined through a summation circuit and produce nearly zero temperature
20 coefficient.

SUMMARY OF DISCLOSURE

The circuit consists of

1. An analog read-out interface circuit for ion sensor
- 25 2. A tungsten temperature interface circuit, comprising:

By summation of the positive temperature coefficient of the ISFET and the negative coefficient of the resistor temperature dependence the drift compensation is achieved.

LIST OF ACCOMPANYING DRAWINGS

30 Figure 1

Shows the Block diagram of analog read-out interface circuit with the temperature sensor and the Constant voltage constant current (CVCC) circuit

Figure 2

Shows the schematic of the analog read-out interface circuitry with temperature compensation.

(1) shows the temperature sensor

5 (2) shows the Constant Voltage Constant Current Circuit

(3) shows the summation circuit

Figure 3

Shows the schematic of the temperature sensor circuit

10Figure 4

Shows the schematic of the Constant Voltage Constant Current (CVCC) circuit

Figure 5

Shows the schematic of summation circuit

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In describing the preferred embodiments of the present invention as shown in Figures 1 to 4 specific terminologies shall be used for the sake of clarity in the description.

However, it is to be noted that the present invention is not intended to be limited to the specific terminologies so selected and it is to be understood that each specific terminology shall include all technical equivalents operating in a similar fashion to accomplish a similar objective/purpose.

The method and circuit is invented that consists of

101. An analog read-out interface circuit for ion sensor, comprising;

- i. a constant voltage constant current circuit, tungsten temperature sensor read-out circuit and summation circuit; with option to adjust temperature coefficient(TC) of temperature sensor and output voltage level

152. A tungsten temperature interface circuit, comprising:

- i. a tungsten resistor that provides negative temperature coefficient (-TC),
- ii. a differential amplifier circuit that provides option to tune temperature coefficient of tungsten resistor.

20 Fig. 1 shows the proposed analog readout-interface readout circuit for pH sensor. It consists of three major components: a tungsten temperature sensor interface circuit (A) (1), constant-voltage-constant-current (CVCC) circuit (B) (2) and a summation circuit (C) (3). The principle of this readout circuit is to cancel the positive temperature coefficient of ISFET with the negative temperature coefficient of tungsten resistor device.

25

Temperature coefficients of both devices can be combined through a summation circuit (3) and produce nearly zero temperature coefficient. Thus, the ISFET temperature dependence characteristic is improved.

(A) Tungsten Temperature sensor interface circuit

Temperature is one of the factors affecting ISFET pH measurement according to Nernst Equation. Inaccuracy of the measurement will occur if it is not properly taken into account. In this invention, Tungsten temperature sensor is used to improve the ISFET temperature dependence.

The Integrated ISFET and temperature sensor reduces the size of bulky pH electrode. The response time is faster since it is exposed or thinly exposed to acidic or basic solution. Unlike diode or thermistor, Tungsten temperature sensor behaves linearly for Resistance vs Temperature. Unlike Thermocouple, Tungsten temperature sensor can give more accurate result and does not require cold junction. Integrated ISFET with temperature sensing element can also be fabricated on the same wafer and the complete product shall sense the same solution temperature.

An interfacing circuit configuration of this temperature sensor is shown in Fig. 2. A variable resistor, VR_{10} (5), and fixed resistors, R_1 - R_4 (4), are used to control the current and temperature coefficient. By adjusting VR_{10} (5) to the right value, the temperature coefficient of temperature sensor can be tuned closely to ISFET temperature coefficient, but its value still negative. It is important to have this option because fabricated ISFET has high possibility to differ from expectation.

20

(B) CVCC circuit

The sensing circuit of Fig.3 detects the ion concentration of the solution with features of constant voltage/constant current operation mode, and floating reference electrode. The drain terminal of the transistor ISFET is connected to the output terminal of the first amplifier OP1 (8), where a constant voltage, e.g., 0.95 volts in the figure, is fed to its positive terminal (15). The negative terminal is connected to the output terminal (9). The source terminal of the transistor ISFET is coupled with the negative terminal of the second amplifier OP2 (10), and coupled with the ground via a resistor R_{15} . A constant voltage, e.g., 0.75 volts in the figure, is fed to the positive terminal of the second amplifier OP2 (14). The output terminal of the second amplifier OP2 is coupled with the reference electrode Ref of the transistor ISFET (11). Another

amplifier OP3 is connected as a buffer (12). With this configuration, two constant voltages input to the two positive terminals of the amplifiers cause the source terminal S' (10) and the drain terminal D (8) of the transistor ISFET to keep a constant drain-source voltage difference. The solution of the ion concentration creates the connection between the reference electrode 5(11) and gate sensing membrane (terminal G) (13). The potential difference between the gate sensing membrane and the reference electrode Ref is determined by the ion concentration of the solution.

(C) Summation circuit

10 The read-out circuitry is completed by feeding electrical signal generated by both temperature sensor and CVCC circuit into summation circuit that mutually offset their temperature coefficient and produces a temperature independent output signal. Fig. 4 shows circuit configuration of summation circuit. It consists of an operational amplifier and four additional resistors. The output voltage level of summation circuit can be adjusted by controlling input 15 voltage of Vref (16).

This invention is designed at circuit level and simulated using MIMOS 0.35um CMOS technology. The simulated result demonstrates that temperature dependence of ISFET 20 improved from 1.42mV/°C to less than 0.2mV/°C over a temperature range of 0°C to 65°C. The complete layout of this analog read-out interface circuit has been implemented for fabrication, waiting for the complete chip to come out.

According to a preferred embodiment of the present invention, there are the following circuits:

25

1. Circuit of temperature Sensor
2. Constant Voltage Constant Current Circuit
3. Summation Circuit

We hereby claim the following:

1. A method for an adaptable analog read-out interface circuit for ISFET based sensor that improves the temperature dependence of the ISFET comprising the steps of:
 - (1) summation of the positive temperature coefficient of the ISFET and the negative temperature coefficient of the RTD (resistor temperature dependence) of a tungsten temperature sensor;
 - (2) tuning of the drift compensation with a variable resistor
2. An adaptable analog read-out interface circuit for ISFET based sensor comprising a means to tune the drift compensation, a means to provide the drift compensation and a means for the ISFET based sensing.
3. The circuit as claimed in 2, wherein the means to provide the drift compensation delivers a negative temperature coefficient using resistor temperature dependence (RTD) of a tungsten temperature sensor.
4. The circuit as claimed in any of claims 2 and 3, wherein the negative temperature coefficient of the drift compensation means is added to the positive temperature coefficient of the ISFET and by this compensates the temperature dependant drift of the ISFET.
5. The circuit as claimed in any of claims 2 to 4, wherein the means to tune the drift compensation comprises one variable resistor.
6. The circuit as claimed in any of claims 2 to 5, whereby the means for the ISFET based sensing is used as Ph-sensor.
7. A circuit arrangement for an adaptable analog read-out interface circuit for ISFET based sensor, comprising:
 - a Wheatstone Bridge which is connected to the input terminals of the OP Amp for a temperature coefficient (TC) controller circuit;
 - an ISFET which is connected to a Constant Voltage Constant Current circuit (CVCC);

an OP Amp that connects the TC controller circuit and the CVCC circuit for summation

8. The circuit arrangement as claimed in 7, where the Wheatstone Bridge is built from a tungsten temperature sensor and 4 fixed resistors.

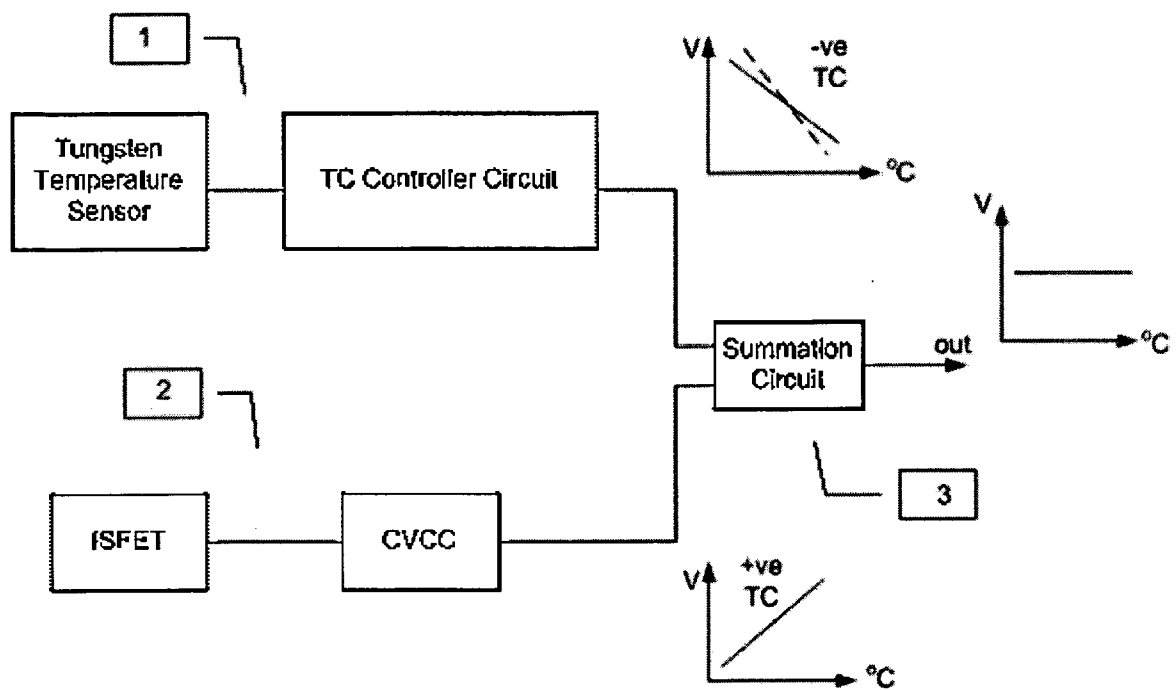


Figure 1: Block diagram of analog read-out interface circuit

2/5

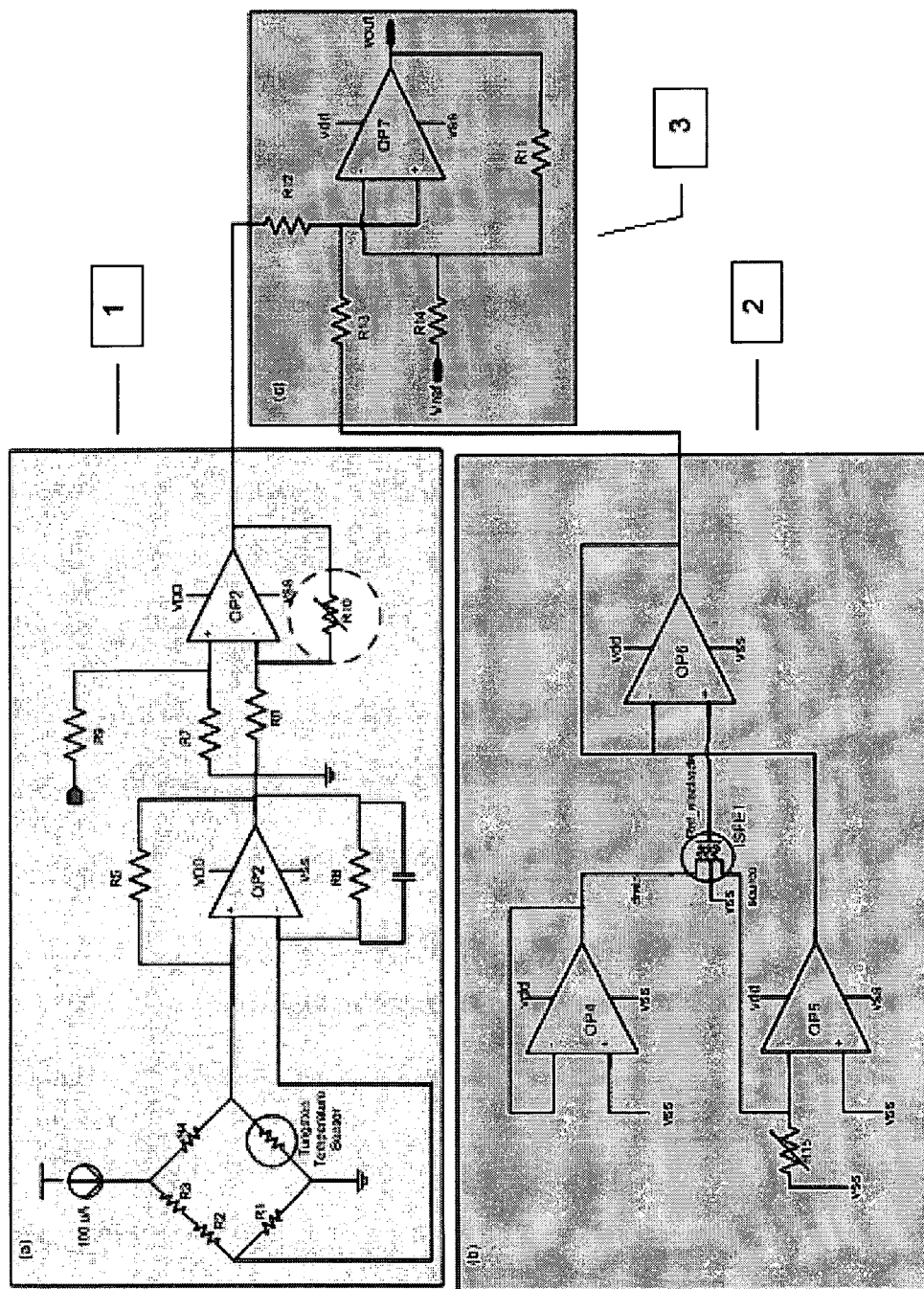


Figure 2. Analog read-out interface circuitry with temperature compensation

3/5

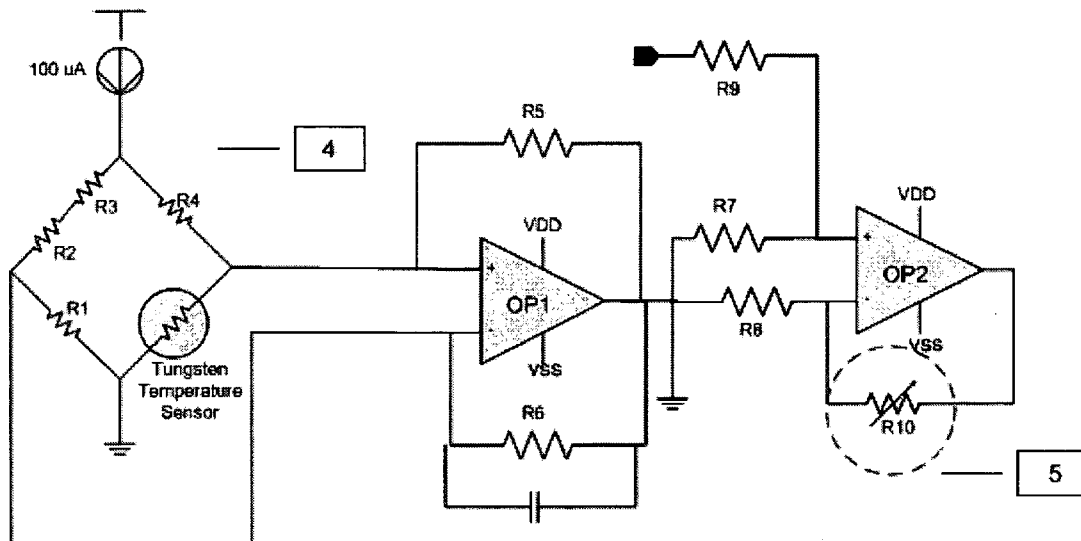


Figure 3. Circuit schematic of temperature sensor

4/5

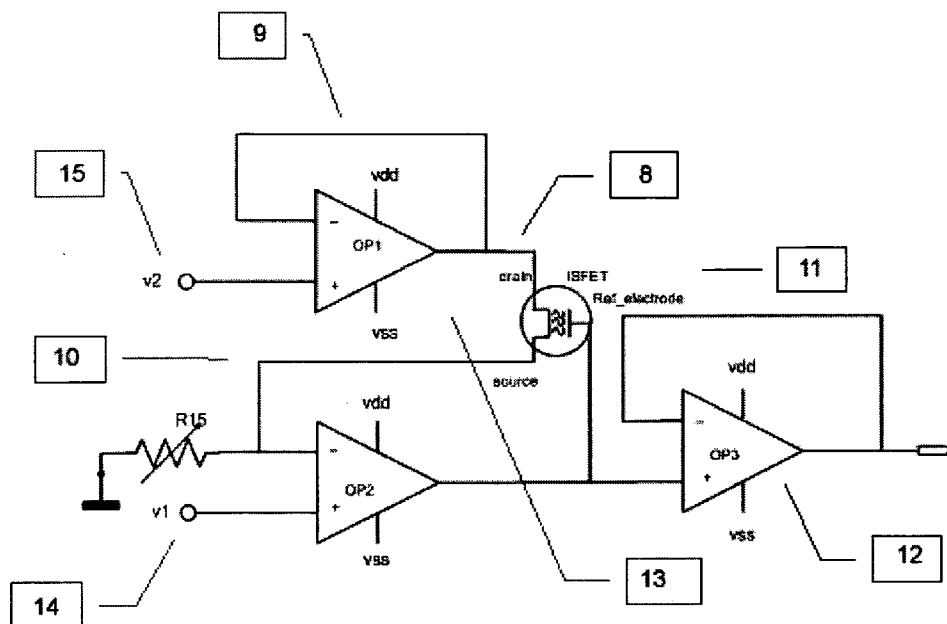


Figure 4. Constant voltage constant current (CVCC) circuit

5/5

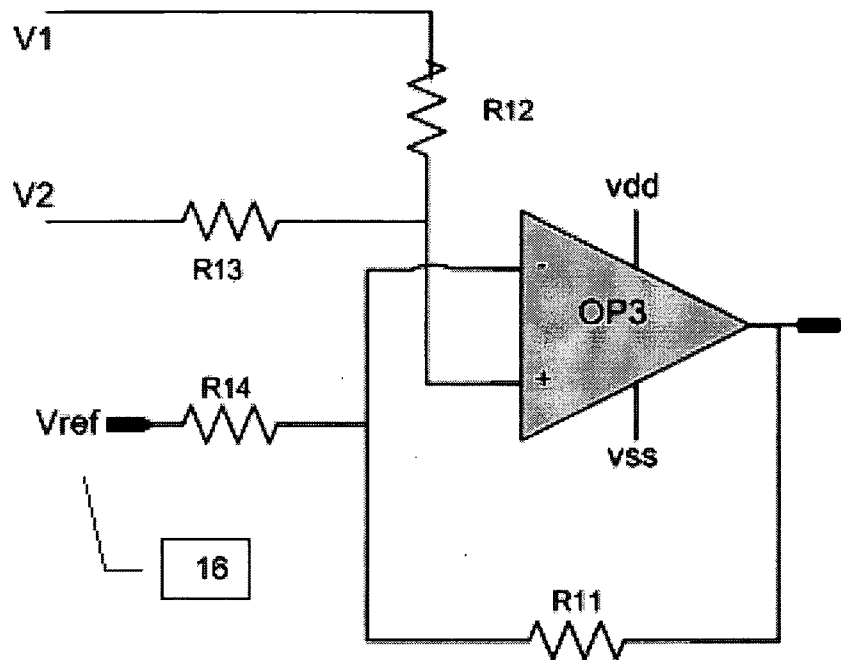


Fig. 5. Circuit schematic of summation circuit